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PATENT SPECIFICATION

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(54) A PROCESS FOR IMPROVING THE FUNCTIONAL PROPERTIES OF PROTEIN MATERIAL

(71) We, STANDARD OIL COMPANY, a corporation organized and existing under the laws of the State of Indiana of 200 East Randolph Drive, Chicago, Illinois 60601, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to the improvement of the functional properties of proteinaceous materials such as single-cell proteins, plant proteins, whey solids, and mixtures thereof. More precisely, this invention involves subjecting the protein-containing material to a controlled pH, temperature, and time treatment which results in the improvement of the functional properties. For purposes of this invention, yeasts are considered as being separate from the plant proteins and are included within the single-cell protein category.

In recent years much attention has been directed toward the development of protein materials which can be incorporated in foods or food additives suitable for human consumption. Looking at plant proteins available today, it has been observed that these materials contribute to the off flavor, after flavor, undesirable color, unbalanced nutrients, or unacceptability in various food products. Similarly, untreated single-cell protein materials have been observed to have adverse effects on dough property and the bread quality. As would be expected, mixtures of single-cell and plant protein material have undesirably functional characteristics from each of the separate protein source materials.

The use of single-cell materials as a source for protein and the problems associated therewith can be better understood by looking more closely at a member selected from this class of materials, such as yeast cells. Yeast cells have the characteristic flavor and aroma which are affected to some extent by the growth conditions and the after-harvest processing conditions. They have a complicated organoleptic profile which consists of both pleasing and unpleasant flavors. One of the reasons limiting the use of yeast materials in food systems is the deleterious effect of its "yeasty" flavor. Where it is desirable to use yeast material at high levels for protein enrichment, a product of bland taste is preferred. Although the majority of yeasty flavor components can be easily removed from the yeast cells by a hot water extraction method, the use of such a process results in the loss of 15 to 20% in product yield. Furthermore, the extracted cells will retain some bitter, beany, and metallic off-taste. The loss in yield may be compensated by the value of the meat-flavored extract as a by-product, but the poor flavor of the cell product would need definite improvement. In addition, the hot water-extracted yeast cells contain about 0.6 to 1.0% phosphorus and 0.01 to 0.02% calcium. In order to achieve a nutritional balance of the calcium-phosphorus ratio for a food system in which such yeast is used, additional calcium may be necessary.

Particular attention has been directed to the use of single-cell protein materials, such as yeast, as a replacer for egg solids and nonfat dry milk (NFDM). For example, in the bakery industry, 2 to 3% nonfat dry milk is normally used as an additive to improve the physical and nutritional quality of bread. However, in view of the increasing cost and decreasing availability of milk, many bakers are looking for a substitute. Although certain products derived from soy proteins have gained some acceptance, the active search by food technologists for a suitable substitute for milk in food products continues.

In this regard we have observed that during the fermentation and baking of bread dough, the wheat protein (gluten) forms the structure to hold the small

bubbles of gas which are generated. This functional property permits the bread to rise and results in the production of bread having good volume and fine crumb structure. However, when untreated single-cell materials, such as dried inactive yeast, are added to bread dough to replace 2% nonfat dry milk, undesirable changes are observed in the property of the dough which adversely affect the bread quality. Typically, dough which contains untreated yeast is soft, stringy, sticky and moist to the extent of rendering it difficult to handle. In fact, the dough has poor machinability characteristics which are detectable from the mixing to the final proofing stage. The inferior property of the dough is probably due to the poor water absorption and the strong reducing property of the thiol group in the yeast cell which damages the gluten structure. We have now found that materials such as yeast, plant, whey solids and combinations thereof can be treated according to the process of this invention to yield products highly suitable for replacing egg solids and nonfat dry milk. During the treatment of the yeast cells in accordance with the present process, several things happen which improve the functional property of the cell. The yeasty off-flavor is greatly reduced and cell material becomes significantly bland in taste by heating the yeast cells under controlled pH reaction conditions. A large amount of buffering materials is released from the cell by the heating process, which increases the buffering capacity of the food system when they are incorporated as dry yeast cell material. The saponification of lipid material gives rise to a soap material which is a good emulsifier. Also, heating under alkaline pH conditions will enhance the auto-oxidation of the thiol groups and the water holding capacity.

According to this invention, there is provided a process for treating protein materials selected from single-cell protein material, plant protein material, whey solids, or mixtures thereof in a manner whereby the color, flavor, nutritional value, and functional properties of said materials are improved for food use.

According to the present invention there is provided a process for improving the functional properties of protein-containing materials comprising the steps of:

(a) preparing an aqueous slurry of a protein-containing material selected from (1) single-cell protein, (2) plant protein, (3) whey material, and (4) mixtures of single-cell protein with plant protein, whey solids, or both plant protein and whey solids, said mixtures containing from 1 to 99 weight percent of the single-cell protein component;

(b) heating the aqueous slurry to a temperature of from 75° to 100°C.;

(c) adjusting the pH of the heated slurry to within the range of 6.6 to 8.0 by adding a compound selected from anhydrous ammonia, ammonium hydroxide, calcium hydroxide, sodium hydroxide, sodium bicarbonate, calcium sulfate, potassium carbonate, calcium carbonate, sodium carbonate, potassium hydroxide, magnesium hydroxide and mixtures thereof;

(d) maintaining the heated, pH-adjusted slurry at said conditions for a time period of from 1 to 120 minutes; and

(e) drying the material from step (d).

In carrying out the process of the invention the aqueous slurry is treated with a basic compound, preferably a calcium compound, and may be fortified with an amino acid such as methionine or cystine. An aqueous slurry of the protein material is prepared and heated to a temperature of from 75° to 100°C. and the pH of the heated protein material is adjusted within the range of 6.6 to 8.0, preferably 7.2 to 7.6, by adding a pH adjusting compound. The pH adjusting compound can be selected from anhydrous ammonia, ammonium hydroxide, calcium hydroxide, sodium hydroxide, sodium bicarbonate, calcium sulfate, potassium carbonate, calcium carbonate, sodium carbonate, potassium hydroxide, magnesium hydroxide, and mixtures thereof, especially mixtures of calcium hydroxide and calcium carbonate or calcium sulfate. Additionally, the pH adjustment can be accompanied by the agitation and oxidation of the single-cell protein. The pH adjusted solution is maintained at temperature for a period of 1 to 120 minutes, preferably 1 to 10 minutes and most preferably about 2 minutes and then dried. Alternatively the pH adjusted slurry, after having been maintained at the aforementioned conditions of pH and temperature for from 1 to 120 minutes, is separated into (1) a protein extract and (2) a base-treated protein material, particularly with a basic calcium compound, wherein the base-treated protein material is removed, water washed and dried with or without the addition of amino acids. The protein extract can be heated to an increased concentration and dried for use as a seasoning ingredient.

By the practice of this invention one can prepare a proteinaceous material having improved functional properties from single-cell protein, plant protein, whey solids, or mixtures thereof.

It is believed that any microbial cell material, plant protein, whey solution, or mixtures thereof can be treated according to the process of this invention, although this invention is particularly suited for processing yeasts such as *Candida utilis*. In a fully integrated, continuous system, microbial cells are conveniently grown in a first fermenting stage where oxygen and a suitable substrate, such as liquid or gaseous hydrocarbons or oxygenated hydrocarbons such as carbohydrates or alcohols, together with a nutrient solution containing minerals are fed to a stirred reactor containing the microorganisms. In a continuous fermentation at steady state, a portion of the reacting mixture is withdrawn at a constant concentration of microorganisms. The concentration of the cells is typically increased by mechanical or evaporative means. As the microorganism concentration increases, a portion of the reacting mixture is withdrawn from the stirred reactor and the microorganisms are separated from the withdrawn reaction mixture.

By way of illustration, bacteria such as those listed in Table I, yeasts such as those listed in Table II, and fungi such as those listed in Table III are suitably single-cell protein materials for use as starting materials in the practice of this invention.

TABLE I
Suitable Bacteria

Acetobacter sp.
Arthrobacter sp.
Bacillus subtilis
Corynebacterium sp.
Micrococcus sp.
Pseudomonas sp.

TABLE II
Suitable Yeasts

Candida curvata
Candida lipolytica
Candida pulcherima
Candida utilis
Hansenula anomala
Pichia farinosa
Oidium lactis
Saccharomyces carlsbergensis
Saccharomyces cerevisiae
Saccharomyces fragilis
Trichosporon cutaneum

TABLE III
Suitable Fungi

Aspergillus niger
Aspergillus glaucus
Aspergillus oryzae
Aspergillus terreus
Aspergillus itaconicus
Penicillium notatum
Penicillium chrysogenum
Penicillium glaucum
Penicillium griseofulyum

Candida utilis, *Saccharomyces cerevisiae*, *Saccharomyces fragilis*, or *Saccharomyces carlsbergensis* are suggested single-cell starting component materials for the process of this invention, because each is approved by the U.S. Food and Drug Aministration as suitable for use in food products.

The plant protein material is advantageously selected from oil seed protein materials such as soy flour, defatted soy flour, soy flakes, soy protein isolates and concentrates, cotton seed flour, cotton seed protein isolates and concentrates, peanut flour, peanut protein isolates and concentratess, sesame seed flour, sesame

seed protein isolates and concentrates, corn grits, corn protein isolates and concentrates, gluten, cereal protein isolates and concentrates, rapeseed flour and rapeseed protein isolates and concentrates.

The whey material can be whey solids in the form of an aqueous solution, condensed suspension of crystals, or a dried powder. The whey may be derived from the processing of Cheddar, Brick, Edam, Parmesan, Gouda, Emmenthaler (Swiss), or other cheeses.

The accompanying schematic diagrams (Figures 1 to 3), Tables IV to VIII, and Examples I to XI are illustrative, without implied limitation, of this invention. In the Examples, except where otherwise specified, all percentages are by weight.

EXAMPLE I

The following three testing samples were prepared from a 10% solids yeast cell slurry under the conditions as described in the diagram shown in Figure 1.

(a) untreated spray-dried cells

(b) heated at 95°C. and pH 5.9 for 30 minutes

(c) heated at 95°C. and pH 7.5 (0.88 g. NaOH/100 g dry cell) for 30 minutes.

The samples were submitted for bread-baking test. The results are summarized in Table IV. The best result, as it is comparable to that of NFDM, is from the sample prepared by heating at pH 7.5. The most significant improvement is in its dough property. The baking test results indicate the importance of the pH effect during the heat treatment.

TABLE IV

Performance in Dough Handling

As Additive (2%)	Characteristics
NFDM	Good in mixer, rounding, and moulder. Normal into oven.
Untreated Cells	Not tolerant to mixer. Sticky and stringy off mixer. Recovered for rounding. Flat into oven.
Cells treated* at pH 5.9	The same as that of untreated cells.
Cells treated* at pH 7.5	Equal to that of NFDM.

*Heating at 95°C. for 30 minutes under open air with constant agitation.

As previously mentioned, untreated yeast cells have a high content of thiol groups. Soluble compounds such as glutathione and cystine, as well as the thiol group in the water soluble protein are active materials which will weaken the gluten structure by the sulfhydryl-disulfide interchange reaction during the dough mixing and proofing. The thiol group is readily oxidized, especially under heating at increased pH with trace amounts of metal ions. Experimental results in Table V illustrate the effect of heating at increased pH in order to achieve the auto-oxidation of thiol in *Candida utilis* cells. Two things are indicated: (1) the thiol may be oxidized to various compounds beyond the less oxidized form of disulfide as indicated by the data showing that 61% of the total thiol in yeast is lost through the auto-oxidation from heating at the pH of 7.5, while only 30.5% is lost at the pH of 5.9, and (2) almost all of the remaining thiol groups are in reactive form which apparently represents the thiol groups of insoluble protein existing intracellularly and unreacted. These residual thiol groups in the treated yeast cell are most probably inactive during bread-making when the cells are mixed into the dough. Only soluble thiol compounds such as glutathione and cystine will affect the gluten structure.

TABLE V
Effect of Heating at Increased pH on the Auto-oxidation of Thiol in Yeast Cells[1]

Cell Treatment	Reactive SH (milli-equivalents/ gram)	Total SH (milli-equivalents gram)	SH Loss %
Untreated	21.6	30.7	0
pH 5.9[2]	12.9	21.3	30.5
pH 7.5[2]	10.4	12.0	61.0

[1] *Candida utilis* ATCC 9256. Continuous culture grown on ethanol at O_2—limiting condition.

[2] Heating at 95°C. for 30 minutes under open air with constant agitation.

[3] Analyzed by the method of C. C. Tsen and J. A. Anderson ("Determination of Sulfhydryl and Disulphide Groups in Flour and Their Relation to Wheat Quality" *Cereal Chem.* 40: 314—323, 1963).

EXAMPLE II

A sample was prepared by digesting a 10% torula yeast cell slurry at 75°C. and pH 7.0 for one hour. The baking test results as summarized below indicate that its quality is comparable to NFDM as an additive to bread-baking.

Sample	Bread Score	Dough Property
Untreated cell	83	sticky and wet
Treated cell	97	normal
NFDM	98	normal

EXAMPLE III

The experiment of calcium treatment was carried out as outlined in Figure 2.

Aliquots of 200 ml of yeast cream which contains 10% cell by weight, are dispensed into each of the 400 ml beakers, with or without the addition of various calcium compounds as listed in Table VI. The amount of calcium added is calculated from the basis of 2% phosphorus in the aliquot of cell material and of a ratio of calcium to phosphorus of one.

The slurry was heated rapidly to 80°C. by a submerged steam coil under constant stirring. At the end of 10 minutes' cooking period, the heated material was quickly cooled down to room temperature by circulating the cooling water through the coil. The pH of the treated slurry was measured and adjusted, as necessary, to a value of 6.7. The cell material was separated, washed, and dried. The yeast extract was directly subjected to sensory test without further treatment. The results of the treatment using various calcium compounds as compared to the control are summarized in Tables VI, VII, and VIII.

The experiment results indicate that:

1. A bland-taste cell material is obtainable by cooking the yeast with $CaCO_3$, where the pH is close to the neutral. Bad flavors are produced when the cells are reacted with $Ca(OH)_2$ at an alkaline pH, or with $CaCl_2$ at an acidic pH.

2. The yeast extracts obtained from the treatment with various calcium compounds are significantly different in their color, odor, and taste from that of the control. The best choice is still the one from the $CaCO_3$ treatment.

3. Tasting of the unfractionated products prepared from the above calcium treatments indicated that calcium carbonate ($CaCO_3$) treated material gave the best flavor. This means that a control of pH close to 7 is very critical to the flavor of the treated yeast products.

TABLE VI
The Calcium-treated Yeast Cells[1]

Treatment[2]	pH[3]	Yield[4]	Color	Flavor[5]
Control	6.2	84.3	Whitish	Slightly bitter
5.0% $CaCO_3$	6.7	85.0	Whitish	Bland
3.7% $Ca(OH)_2$	9.2	80.0	Cream	Fairly bitter
5.5% $CaCl_2$	5.6	84.4	Pinkish	Fairly bitter and astringent

[1]Cooked at 80°C. for 10 minutes, washed, and dried.
[2]The weight of calcium compound added is based on the dry weight of yeast cell which contains 2% P. The ratio of Ca/P is about 1.
[3]Unadjusted pH reading of the cooked slurry.
[4]After the pH of the slurry is adjusted to 6.7.
[5]Sensory test of a 5% suspension in water.

TABLE VII
The Yeast Extract From Various Calcium Treatments[1]

Treatment[2]	Color	Color Intensity	Odor	Off-Flavor[3]
Control	Orange	+++	Yeasty	Yeasty and beany
5.0% $CaCO_3$	Yellowish	+	Hydrolyzate	Not detected
3.7% $Ca(OH)_2$	Yellowish	+	Butyrous	Slightly beany
5.5% $CaCl_2$	Orange-Yellowish	++	Yeasty	Slightly beany

[1]Cooked at 80°C. for 10 minutes, separated from the cell material.
[2]The weight of calcium compound added is based on the dry weight of yeast cell.
[3]All of the samples give pleasing meaty flavor.

TABLE VIII
The Comparison of Egg Replacement Quality Between Calcium-treated and Untreated Blend Products In Yellow Cake Tests at 50% Egg Replacement Level

Composition of Samples	Total Score* Yellow Cake	Expert Panel Comments
80% Full Fat Soy Flour 20% inactive dry yeast (treated according to Example XI)	90	Bright color, finer crumb, egg taste, excellent body
80% Full Fat Soy Flour 20% inactive dry yeast (untreated)	84	Dry texture, lacks flavor, soy taste, crumbles, burning, aftertaste
80% Defatted Soy Flour 20% inactive dry yeast (treated according to Example IX)	96	Excellent body, well defined crumb structure clean flavor
80% Defatted Soy Flour 20% inactive dry yeast (untreated)	74	Poor body, good flavor, dry mouthfeel, open structure
80% Triticale Flour 20% inactive dry yeast (treated according to Example X)	94	Excellent body, sweet egg flavor, good structure
80% Triticale Flour 20% inactive dry yeast (untreated)	90	Gray color, gummy

**Yellow cake score.* Maximum possible score is 100 for best overall quality. The score for yellow cakes with 100% egg ranges from 94 to 96.

EXAMPLE IV

Yeast cream (containing 10—19% cell by weight) was heated to 80°C. The pH of the flowing stream was adjusted to within the range of 7.2 to 7.6 by blending with an aqueous suspension of 1.7 weight percent calcium hydroxide ($Ca(OH)_2$) and 8.5 weight percent calcium carbonate ($CaCO_3$). The stream was held at temperature and pH for 2 to 4 minutes, then spray dried at rates up to 2,500 lb/hr. of dry product.

EXAMPLE V

Mixtures of yeast cream (10—19% cell by weight) and cheese whey (5—40% total solids by weight) were blended to levels of 27 to 47% whey (dry basis, by weight). The mixed stream was heated to 80°C, then treated with a combined aqueous suspension of calcium carbonate ($CaCO_3$, 8.5% by weight) and calcium hydroxide ($Ca(OH)_2$, 1.7% by weight) to effect a system pH within the range of 7.0 to 7.6. The process stream was held at 80°C and 7.0—7.6 pH for 2—4 minutes, then spray dried at rates up to 80 lb/hr. of dry product output.

EXAMPLE VI

The process of Example V was repeated using sodium hydroxide (NaOH, 5.6% by weight) to adjust the pH to within the range of 6.8 to 7.0.

EXAMPLE VII

Figure 3 outlines the process of the production of modified plant protein.

Calcium carbonate and calcium hydroxide are added to an aqueous soy protein solution until the pH is between 6.5 to 7.5. The aqueous suspension is heated at 90°C. for 30 to 60 minutes and then dried.

EXAMPLE VIII

The same as Example VII except that methionine is added before the aqueous suspension is heated.

EXAMPLE IX

Twenty grams of Torutein* (inactive dried yeast) was mixed with eighty grams of defatted soy flour. Eight hundred grams of water was added to form an aqueous mixture of Torutein and defatted soy flour. 1.7 grams of calcium hydroxide ($Ca(OH)_2$) and 3.6 grams of calcium carbonate ($CaCO_3$) were added to the aqueous mixture. The aqueous mixture was heated up to 88°C. over a period of 40 minutes, the temperature was maintained at 88°C. for 60 minutes, and allowed to cool to 21°C. over a period of 20 minutes. The cooled product was dried by freeze drying.

*Registered Trade Mark.

EXAMPLE X

The same as Example IX except that triticale flour is used in place of defatted soy flour.

EXAMPLE XI

The same as Example IX except that full fat soy flour is used in place of defatted soy flour.

The many uses and advantages of the treated products produced in accordance with this invention become apparent when it is realized that such products replace egg yolk and/or nonfat dry milk in an extensive array of food products. More particularly, it has been observed that the said products can replace nonfat dry milk in formulations which include such bakery goods as brownies, chocolate cake, chocolate krinkles, chocolate puddings, cinnamon rolls, cinnamon swirl loaf, coffee cake chemically leavened, coffee cake yeast raised, fudge, hamburger buns, high ratio yellow cake, nut fingers, pancakes, pecan loaf, pound cake, shortbread cookies, waffles, wheat flour tortillas, doughnut, yellow cake mix and related products.

WHAT WE CLAIM IS:—

1. A process for improving the functional properties of protein-containing materials comprising the steps of:

(a) preparing an aqueous slurry of a protein-containing material selected from (1) single-cell protein, (2) plant protein, (3) whey material, and (4) mixtures of single-cell protein with plant protein, whey solids, or both

plant protein and whey solids, said mixtures containing from 1 to 99 weight percent of the single-cell protein component;

(b) heating the aqueous slurry to a temperature of from 75° to 100°C;

(c) adjusting the pH of the heated slurry to within the range of 6.6 to 8.0 by adding a compound selected from anhydrous ammonia, ammonium hydroxide, calcium hydroxide, sodium hydroxide, sodium bicarbonate, calcium sulfate, potassium carbonate, calcium carbonate, sodium carbonate, potassium hydroxide, magnesium hydroxide and mixtures thereof;

(d) maintaining the heated, pH-adjusted slurry at said conditions for a time period of from 1 to 120 minutes; and

(e) drying the material from step (d).

2. The process of Claim 1 wherein the protein-containing material in step (a) is a mixture of yeast and whey.

3. The process of Claim 2 wherein the aqueous slurry is maintained at a pH of 7.0—7.6 for from 2 to 4 minutes.

4. The process of Claim 3 wherein the aqueous slurry is maintained at about 80°C.

5. The process of Claim 4 wherein the pH is adjusted by adding calcium carbonate and calcium hydroxide.

6. The process of Claim 1 wherein the protein-containing material in step (a) is a mixture of yeast and whey and the aqueous slurry is maintained at a pH in the range of 6.8 to 7.0.

7. The process of Claim 6 wherein the aqueous slurry is heated to about 80°C. for from about 2 to about 4 minutes.

8. The process of Claim 7 wherein the pH is adjusted by adding sodium hydroxide.

9. The process of Claim 1 wherein the protein-containing material in step (a) is plant protein material.

10. The process of Claim 9 wherein the plant protein material is a soybean material.

11. The process of Claim 10 wherein the aqueous slurry of soybean material is maintained at a pH of from about 6.5 to about 7.5 for about from 30 to about 60 minutes.

12. The process of Claim 11 wherein the pH is adjusted by the addition of calcium carbonate and calcium hydroxide.

13. The process of Claim 12 wherein the slurry is heated to about 90°C.

14. The process of Claim 13 wherein an amino acid is added to the slurry prior to heating.

15. The process of Claim 14 wherein the amino acid is methionine or cystine.

16. The process of Claim 1 wherein the protein-containing material in step (a) is a mixture of yeast and defatted soy flour.

17. The process of Claim 1 wherein the protein-containing material in step (a) is a mixture of yeast and full fat soy flour.

18. The process of Claim 1 wherein the protein-containing material in step (a) is a mixture of yeast and triticale flour.

19. A process for improving the functional properties of a yeast material comprising the steps of:

a) preparing an aqueous slurry of the yeast material;

b) heating the slurry to a temperature of from 75 to 100°C.;

c) adjusting the pH of the slurry to from 7.2 to 7.6;

d) maintaining the heated, pH-adjusted slurry at said temperature and pH for from 1 to 10 minutes; and

e) drying the slurry.

20. The process of Claim 19 wherein the yeast is *Candida utilis*.

21. The process of Claim 19 wherein the slurry is heated to about 80°C.

22. The process of Claim 19 wherein the pH is adjusted by the addition of calcium hydroxide and calcium carbonate.

23. The process of Claim 19 wherein the slurry is maintained at said temperature and pH for about 2 minutes.

24. A process for improving the functional properties of *Candida utilis* yeast comprising the steps of:

(a) preparing an aqueous slurry of the yeast material;

(b) treating the slurry by maintaining the slurry at a pH in the range of 7.2 to 7.6 and a temperature of about 80°C. for about 2 minutes, wherein the pH

is adjusted by the addition of calcium hydroxide and calcium carbonate; and

(c) drying the treated slurry.

25. A process for improving the functional properties of protein-containing materials, comprising the steps of:

(a) preparing an aqueous slurry of a protein-containing material selected from (1) single-cell protein, (2) plant protein, (3) whey material, and (4) mixtures of single-cell protein with plant protein, whey solids, or both plant protein and whey solids, said mixtures containing from 1 to 99 weight percent of the single-cell protein component;

(b) heating the aqueous slurry to a temperature of from 75° to 100°C.;

(c) adjusting the pH of the heated slurry to within the range of 6.6 to 8.0 by adding a compound selected from anhydrous ammonia, ammonium hydroxide, calcium hydroxide, sodium hydroxide, sodium bicarbonate, calcium sulfate, potassium carbonate, calcium carbonate, sodium carbonate, potassium hydroxide, magnesium hydroxide and mixtures thereof;

(d) maintaining the heated, pH-adjusted slurry at said conditions for a time period of from 1 to 120 minutes;

(e) separating the slurry into a protein extract and a residual base-treated protein material; and

(f) washing the residual protein material with water and drying same.

26. The process of Claim 25 wherein the protein-containing material is a yeast.

27. The process of Claim 26 wherein the yeast is *Candida utilis*.

28. A process for improving the functional properties of protein-containing materials according to Claim 1 and substantially as hereinbefore described and exemplified.

29. The product obtained by a process according to any preceding claim.

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1575052 COMPLETE SPECIFICATION

3 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 1

FIG. 1

COMPARATIVE PROCESSES FOR PREPARING A YEAST, PLANT OR YEAST-PLANT PRODUCT TO BE USED AS A REPLACEMENT FOR NONFAT DRY MILK

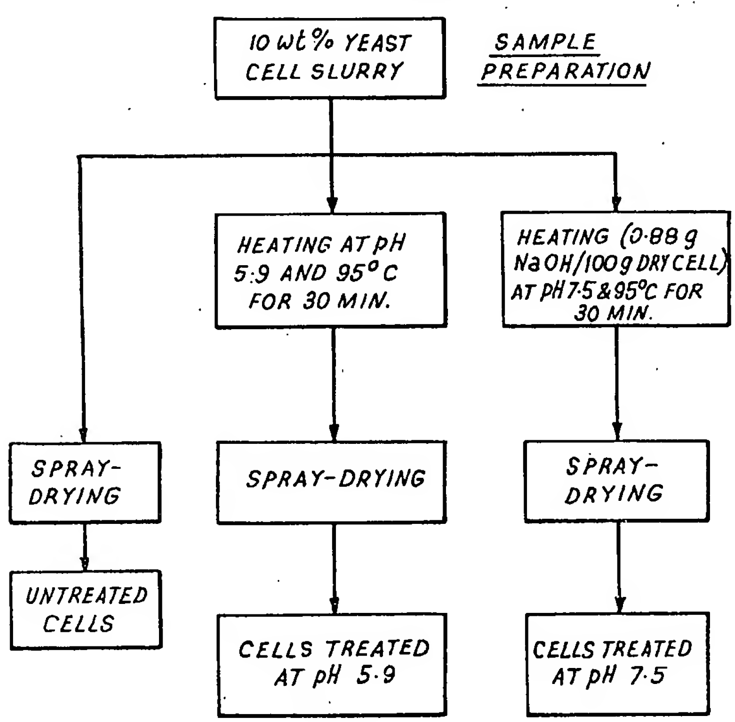

FIG. 2

PROCESS FLOWSHEET

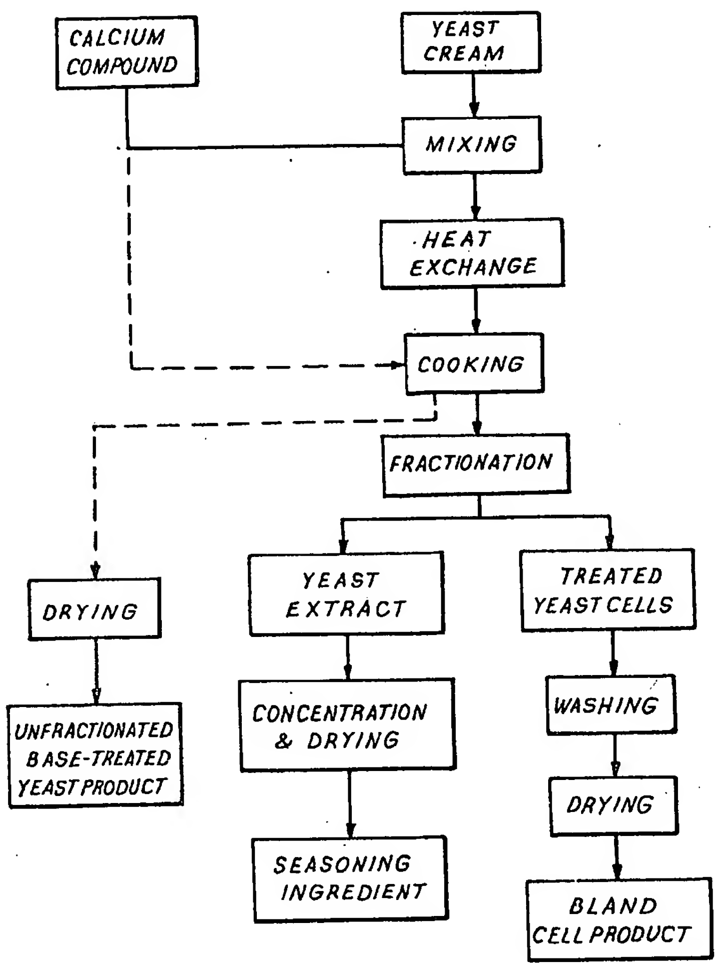

FIG. 3

PRODUCTION OF MODIFIED PLANT PROTEIN